# A Drag Device for Controlled Deorbiting of LEO Spacecraft

(aka Deorbit Drag Device = $D^3$)

# Orbotic Systems

Orbotic Systems is a privately held company based in Thousand Oaks, California. Our mission is to advance human progress in the low Earth orbit (LEO) space environment. Areas of development include space debris remediation, alternative spacecraft propulsion, and nanosatellite technologies. We believe that the time is now for the commercialization of space. By providing a means to make this easy and safe, the space industry can flourish in a new renaissance.

The purpose of this document is to present information on the D3 Deorbit Drag Device and the primary contributions that a commercial version of the device can make to the LEO space sector.

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# Key Messages

**System modulates spacecraft drag force, controls orientation during orbital decay and targets re-entry location**

Goal: develop a simple, reliable, low-cost, non-propulsive system

## Application

- Object mass up to 180kg (~400 lb)
  - CubeSats (as large as 12U)
  - CYGNSS spacecraft
  - ESPA Class spacecraft
  - Orion 38 motor (depleted), such as spent Pegasus Launch Vehicle 3$^{rd}$ stage

## Benefits

- Addresses a number of issues concerning CubeSats
  - Space traffic management, orbital debris mitigation and satellite controllability
- Enable LEO spacecraft (altitudes up to 700km) to meet 25-year Orbital Debris requirement
- Avoid potential collisions; reduce liability and risk of generating new debris
- Provide ability to target unpopulated earth re-entry points
  - Hardware or hazardous materials that survive ballistic entry
  - Alleviate or mitigate risk of human casualty
- Ability to stagger CubeSat (or other spacecraft) constellations via differential drag force
- Improve ground radar visibility of spacecraft (greater surface area profile)

## Status

- Analysis and hardware prototype development nearly completed, currently at TRL 6
- Nov 2021: projected ATP for design of a flight-ready 1U CubeSat
- Targeting flight opportunities in late CY22 via:
  - CubeSat Launch Initiative, Venture Class launch vehicles, ISS deployment

# D3
# Physics

**Orbit lifetime is dependent on:** ballistic coefficient, atmospheric density, solar activity, earth and moon gravitational effects

The ballistic coefficient of a spacecraft ($C_b$ = Area*$C_d$/2*Mass), only variable we can control

- ↑Ballistic Coefficient → Orbit Lifetime↓

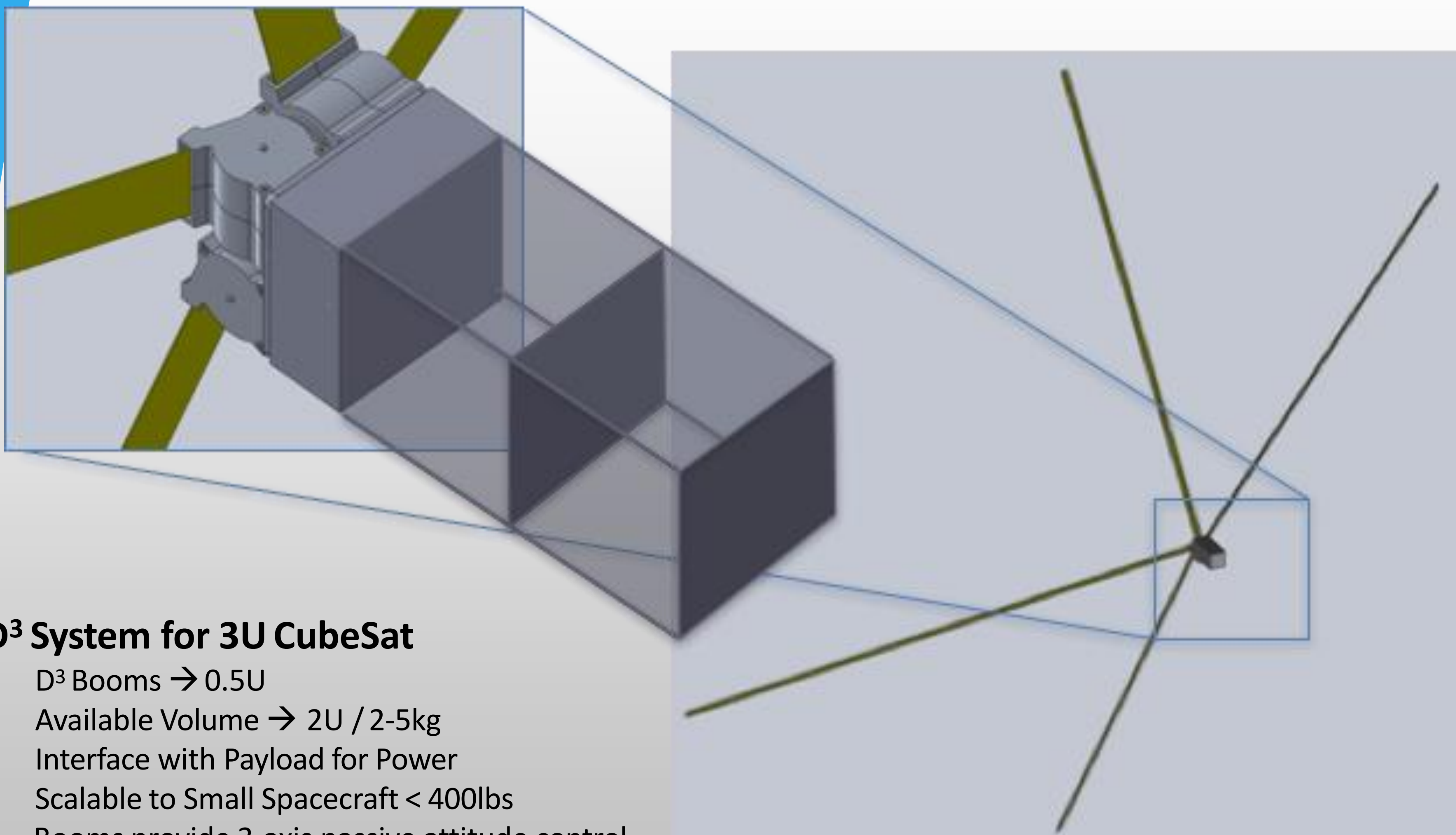
**D$^3$ modulates cross sectional area at specific times via variable boom deployment**

- changes ballistic coefficient
- changes the atmospheric drag the spacecraft receives
- allows control altitude decay profile

**Atmospheric density on orbit varies significantly from what models predict**

- Challenge is for D3 system to be robust enough to accommodate these variations
    - Large ballistic coefficient variation
    - Onboard computation and closed loop control system

# Drag Device

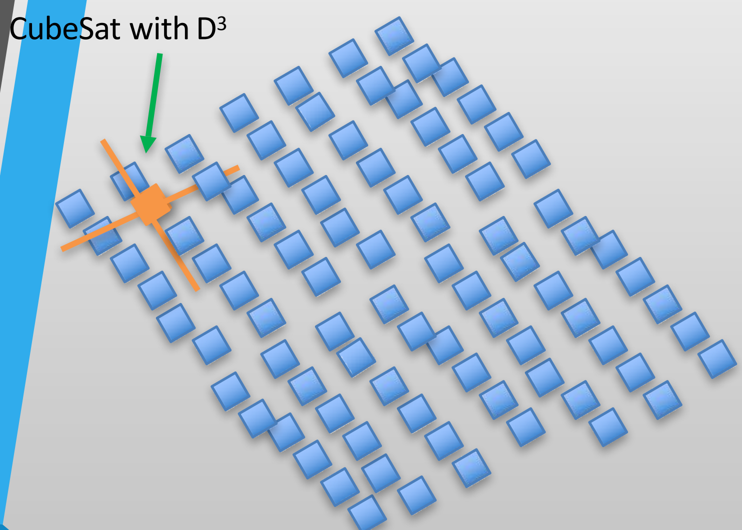


**D³ System for 3U CubeSat**

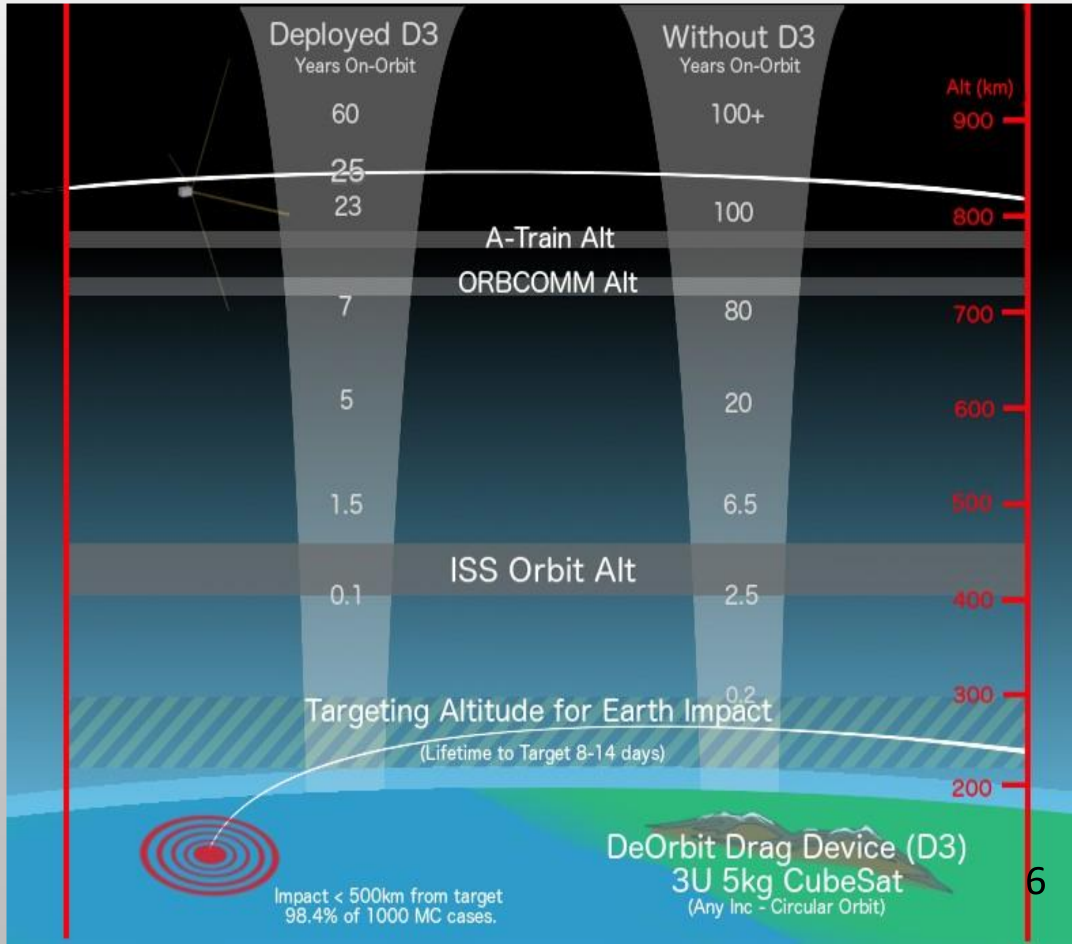
- D³ Booms → 0.5U
- Available Volume → 2U / 2-5kg
- Interface with Payload for Power
- Scalable to Small Spacecraft < 400lbs
- Booms provide 3-axis passive attitude control (drag plus gravity gradient)

# $D^3$ Use Cases

1. **Early Deployment Identification**
   - CubeSat differentiation after deployment from large compliment
2. **Orbital Lifetime Compliance (<25 years)**
   - Allows SC compliance and higher altitudes to be reachable



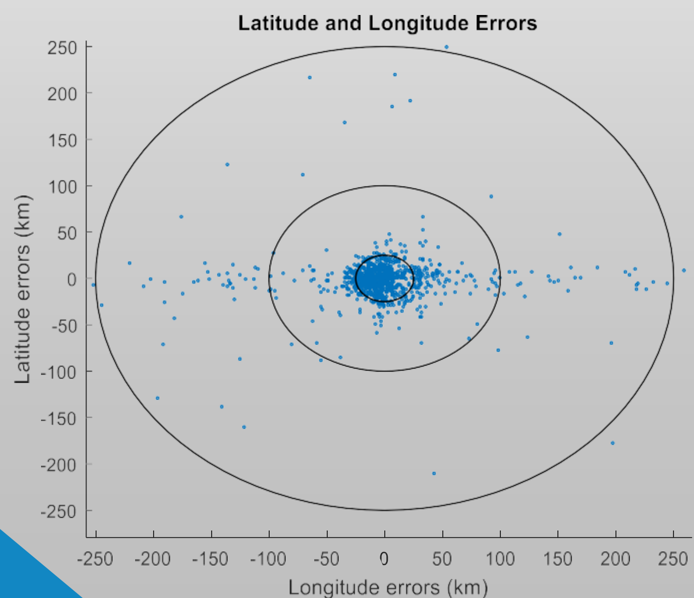

87 CubeSats to be launched on Formosat-5



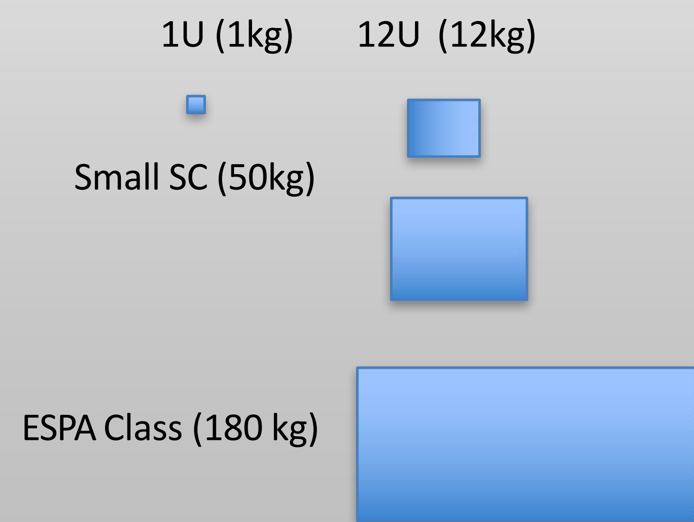
# D3 Use Cases

3. **Altitude Decay Control**
   - Enable coordinated planned orbital decay, avoid active constellations (CYGNSS formation strategy)
4. **Controlled Reentry / Targeted Impact Point**
   - Provide Latitude and Longitude targeting for LEO small spacecraft
   - Variable position booms adjusted during final orbits to meet entry point target
5. **Scalability**
   - D3 System scales from 1U CubeSat up to 400lbm (180kg) Small Spacecraft

**Monte Carlo Analysis of $D^3$ Targeting Accuracy**




**$D^3$ Applicable SC Classes**



# Legal Considerations

- **Why the D$^3$?**
  - Furthering free and open access and use of space for all
  - Decluttering of orbits and increasing accessibility of more space
  - Decreasing potential for harmful interference with other's space activities
  - Decreasing the risks associated with orbital debris and increasing ability to maintain more control of the space craft while in outer space
- **Liability/Risk**
  - Decreasing time in orbit decreases the amount of time for which fault-based liability under Art. III of the Liability Convention applies
    - Decreasing likelihood of in-situ space collision
    - Maneuvering more safely through orbits of other spacecraft
  - Reducing the risk of absolute liability associated with damage caused by the returning space craft on earth under Art. II of the Liability Convention
  - Distinguishing one spacecraft from another more easily in clusters

# Legal Considerations

- **What if it malfunctions?**
  - No change to the liability regime
  - No change to the liability regime whether the device is successful or not
    - Fault-based liability in space
    - Absolute liability for damage on Earth
  - Could pose issues with spacecraft, in higher orbits, which have limited maneuverability to avoid a collision
  - If it malfunctions in a distant orbit, it will not meet the 25 year rule
  - Early planning and specific modeling/testing can aid in mitigation
    - Planning orbits for best and worst case scenarios

# Legal and Practical Considerations

**This solution does not rely on propellant**

- May take this out of ITAR and into EAR
- Less weight
- Reduces complexity
  - No propulsion system
  - Simplifies system integration

**Allows developers to utilize materials that are resistant to re-entry forces (titanium, tungsten, tantalum, etc.)**

- Usage allowed because entry is targeted for unpopulated areas. Decreases probability of human casualty.

**This solution could potentially be used to identify specific spacecraft deployed in constellation, assisting the operator in forming the desired pattern**

**This solution should decrease contingency planning budget**

  - Risk exposure for a fraction of the time
  - Making reserve dollars available for more space activities

**Decisions on commercialization will be made as the technology matures**

# Conclusion

**D3 modulates spacecraft drag force & control orientation during orbital decay**

- Testing is showing positive results
- Analytically demonstrated the D3 works
- Need to verify and validate the technology

**The deorbit targeting algorithm can be used to reduce casualty/property liability both in space and on earth**

**Analysis shows the system can be scaled to larger bodies and the can stagger CubeSat (or other spacecraft) constellations via differential drag force**

**Improve ground radar visibility of spacecraft (greater surface area profile)**

**The system addresses a number of the issues concerning CubeSats: space traffic management, orbital debris mitigation and satellite controllability**

**The use of this system will provide for a significant increase in potential CubeSat users by expanding the operational regime of these satellites.**